How Design Experiments Can Inform a Rethinking of Transfer and Vice Versa

by Joanne Lobato

Limitations with current approaches to the investigation of the transfer of learning in design experiments constrain the type of information that is available to researchers as they make design decisions. This article addresses these limitations by presenting a reconceptualization of transfer, called actor-oriented transfer, which emerged from design experiment work. The merits of this alternative model are considered in terms of the information it provides to design experimenters.

Transfer of learning is a crucial issue for design experiments. Researchers seek information about how learners generalize their experiences from the specific conditions of the design experiment, and this information can in turn inform researchers' decisions in subsequent iterations of the design cycle. I propose that the theoretical assumptions underlying a researcher's model of transfer affect how these design decisions are made. I will begin by discussing limitations with the two most common approaches to transfer in design experiments. Next, I will explore how design experiments can challenge the basic assumptions underlying transfer models, just as they have challenged assumptions about teaching and learning. I illustrate this point by presenting an alternative approach—called *actor-oriented transfer*—which emerged from my own design experiment work. The value of this model is considered in terms of the information it provides to researchers conducting design experiments.

How Transfer Has Been Addressed in Early Design Experiments

Researchers of design experiments have typically addressed transfer in one of two ways. The first method relies on the traditional transfer paradigm (described in detail by Singley & Anderson, 1989). To illustrate, consider the GenScope project (Horwitz & Christie, 1999). GenScope is an exploratory software tool that allows students to investigate ideas in genetics. Considering transfer to be the application of knowledge learned in one situation to another situation, the investigators counted as evidence of transfer improved performance from initial learning tasks to transfer tasks. The transfer tasks embodied the same type of genetics reasoning as the GenScope activities but differed in terms of the organism (worms instead of dragons) and medium (paper and pencil rather than software) (Hickey & Kindfield, 1999).

After the first round of implementation of GenScope, the researchers reported disappointment with the modest levels of transfer and with the fact that the GenScope classes did not show statistically significant improvements over the traditional classes. The transfer measures indicated how far the students were from making the structural connections that experts make but provided little information to illuminate why the students had not performed as well as expected. In an effort to improve performance, the researchers developed paper-and-pencil materials, called *Dragon Investigations*, which used the familiar GenScope dragons to scaffold the specific aspects of genetics reasoning and used the problem formats that were targeted in the transfer tasks. After a series of implementations and revisions, the students showed significant gains on the transfer tasks, an effect that could be attributed to GenScope, but that was enhanced by the Dragon Investigations (Hickey & Kindfield, 1999). However, this approach to transfer also limited the researchers in several ways.

The use of the Dragon Investigations in subsequent iterative cycles was not informed by data regarding the specific generalizations that students may have formed and how the instructional environment may have afforded those connections. Attempts to revise the curriculum in the absence of such information could have undermined the overall effort to produce measures of the generalization of learning. Because of the close alignment of the instruction with the transfer tasks, the gains on the transfer measures may have been due to a training effect. Indeed, the GenScope researchers noted some "loss of evidential validity" in their study but considered it a reasonable compromise given the increase in test scores (Hickey & Kindfield, 1999, p. 20).

These limitations are not unique to the GenScope project: They are endemic to traditional transfer models. According to Barnett and Ceci (2002), ". . . there is little agreement in the scholarly community about the nature of transfer, the extent to which it occurs, and the nature of its underlying mechanisms" (p. 612). Researchers have identified the following theoretical problems with the traditional transfer construct: Traditional transfer experiments rely on models of normative or expert performance and thus can become what Lave (1988) called an "unnatural, laboratory game in which the task becomes to get the subject to match the experimenter's expectations," rather than an investigation of the "processes employed as people naturally bring their knowledge to bear on novel problems" (p. 20). Additionally, transfer researchers often treat context as the task presented to students and analyze the structure of tasks independently of how students construe meaning in the situations (Cobb & Bowers, 1999). Finally, traditional models do not adequately account for the structuring of the sociocultural environment or material artifacts (Beach, 1999).

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Brown and colleagues responded to the transfer debate by purposely blurring the distinction between learning and transfer. They argued that in classroom environments, "any distinction between learning and transfer is ephemeral" because classrooms do not afford the "neat slices of life" found in the laboratory of an initial learning task immediately followed by a transfer task (Campione, Shapiro, & Brown, 1995, p. 39). They redefined transfer as "flexible understanding," referring to students' understanding of domain-specific concepts and more general processes that can be used in the service of continued learning. However, the view that learning and transfer are conceptually indistinguishable could be undermined by a counter example. For instance, Thompson (1994) discussed a case in which learners generalize their understandings to novel situations without any new learning or mental reorganization taking place. Furthermore, it is unclear how equating learning and transfer will guide researchers who seek to enhance students' generalization of learning in a design iteration. Schoenfeld (1999), in his presidential address to the American Educational Research Association, argued that even if one sees transfer as a subset of learning, the need for a renewed theory of transfer remains.

The Emergence of an Actor-Oriented Transfer Model

In my own work, I found it necessary to shift from a traditional view of transfer to an alternative approach. In a design experiment geared to help high school algebra students develop an understanding of slope and linear functions, traditional measures of transfer indicated poor transfer to novel tasks such as finding the slope of slides and roofs (Lobato, 1996). Poor transfer occurred despite high scores on initial learning tasks involving the slope of objects encountered in the experimental curriculum, such as staircases and lines. These results alone, however, did not suggest productive directions for the next iteration in the design cycle. Furthermore, the students might have generalized their experiences from the experimental unit in ways that were not captured by the traditional transfer approach.

Consequently, I reanalyzed the data, this time relying on a definition of transfer as the personal creation of relations of similarity, or how the "actors" see situations as similar—a definition with antecedents in Høffding (1892) and Lave (1988). Høffding asserted that perceived similarity—how the new situation is connected with the thinker's trace of a previous situation—is fundamental to transfer. Thus, rather than predetermining what counts as transfer using models of normative performance, I shifted from what MacKay (1969) called an *observer's* (expert's) viewpoint to an *actor's* (learner's) viewpoint by seeking to understand the processes by which individuals generate their own similarities between problems.

The actor-oriented transfer analysis revealed significant evidence of (reconceptualized) transfer and illuminated how the new situations might be connected with the thinkers' images of previous situations. Looking for evidence of transfer from an actor-oriented perspective necessitated a shift from a consideration of expert understanding of slope to a consideration of the type of conceptions that students could have developed given the instructional treatment. The unit began with an extensive exploration of real staircases, followed by a computer exploration of staircases, and culminated in the use of mathematical "stairs" to determine the slope of a line and other objects. With this in mind, one could see how the students' images of slope were connected to an attunement to affordances for stair steps (e.g., looking for something that appears to afford climbing and has visually connected "up" and "over" components).

To illustrate this point, consider a transfer task depicting a playground slide (including a vertical ladder and a steep ramp, connected on top by a horizontal platform). In this case (Lobato, 1996) two students reported that they would find the slope by dividing the "rise" by the "run." Jarek chose the height of the ladder as the rise and the length of the platform as the run. By contrast, Alison focused on the ladder and located the rise as the length of a diagonal that she superimposed between two rungs on the ladder and the run as the width of the ladder. Although the students' rise and/or run choices were incorrect, they did appear to generalize their experiences from the instructional unit to the transfer task through their connection of slope with images of stairs. Specifically, Jarek's choices of rise and run supported the creation of a stair step on the slide. Alison explained that in order to find the slope, she needed to "measure the steps," indicating that she perceived affordances for "making a staircase" directly in the stairs on the ladder.

Benefits of Using an Actor-Oriented Transfer Approach in Design Experiments

Making Principled Design Decisions

The actor-oriented transfer perspective enabled us to make principled design responses informed by knowledge of students' particular generalizing processes. For example, in the study involving playground slides, the students' generalizations were based on affordances and constraints for staircases, which contributed to the fact that they made rise and run choices that were disconnected from the part of the object that is steep. Furthermore, students had difficulty accounting for how changing various quantities in the situation (such as lengthening the platform of the slide) would affect the steepness of the slide (Lobato, 1996; Lobato & Thanheiser, 2002). This finding suggests that our expert judgments regarding what constituted surface and structure features between the learning and transfer tasks had been unwarranted. Like the GenScope researchers, we made an a priori judgment that the transfer tasks shared the same structural knowledge elements with the initial learning tasks and differed only in terms of surface or "contextual" features. However, the slide situation appeared to present structural complexities for many students (even though it may have represented a surface feature for experts). In the next iterative cycle, the actor-oriented transfer analysis guided us as we created a revised instructional treatment that emphasized reasoning about relationships among measurable attributes of objects in realistic situations (Lobato & Thanheiser, 2002). The students demonstrated noticeable improvements on transfer tasks by selecting rise and run measurements that were connected with the attribute being measured by slope (Lobato & Siebert, 2002).

Reflecting upon several cycles of design led to a more nuanced and differentiated view of levels of transfer. Lobato and Ellis (2002) discussed how a further revision of their design approach to slope resulted in evidence of even more sophisticated levels of

transfer. Identifying levels of increasing sophistication in non-normative or incorrect displays of transfer is related to Minstrell's (2001) articulation of facets of students' understanding of physics. In Minstrell's approach, one can identify a particular facet as indicative of more complex and sophisticated understanding than another facet, even when both facets represent incorrect or non-normative reasoning. One can similarly identify levels of actor-oriented transfer, which is powerful for design studies because moving up levels of sophistication may be linked with successive iterations in the design cycle.

Identifying What Is Salient for Students

We are beginning to identify an instructional basis for actor-oriented transfer by demonstrating how features of instructional environments, including the social nature of the setting, influence what students attend to. These features in turn affect how students generalize their learning experiences (Lobato, Ellis, & Muñoz, in press). We have been able to connect individual students' generalizations to the classroom environment by advancing the notion of *focusing phenomena*, which refers to the regularities in the ways in which teachers, students, artifacts, and curriculum act together to direct students' attention toward certain mathematical properties over others. To illustrate, qualitative evidence from one iterative cycle revealed that all seven interview participants interpreted slope as a difference rather than a ratio. The examination of corresponding classroom data revealed four focusing phenomena that regularly directed students' attention to various differences rather than to the coordination of quantities. The identification of the particular ways in which the classroom practices afforded students' generalizations suggested principled ways in which we could make design responses. Preliminary findings suggest that by regularly directing students' attention to the coordination of covarying quantities, students are more likely to generalize slope as a ratio (Lobato & Ellis, 2002).

Relationships Between Features of Design Experiments and Actor-Oriented Transfer

One of the major contributions of design experiments has been the creation of instructional embodiments of the following shifts in assumptions about learning and teaching: (a) from a focus on the products of learning to learning processes; (b) from teacher-centered to learner-centered classrooms, where the teacher responds flexibly to students' ideas rather than following a fixed lesson sequence; (c) from a reductionistic cognitive view of learning to the recognition that learning is also social in nature (Brown, 1992). Similarly, moving from a traditional to an actor-oriented transfer perspective involves a shift from the determination of transfer based upon cognitive models of expertise to an account of learners' personal generalizing processes within social settings that structure their generalizing experiences.

In addition, a primary goal of a design experiment is to develop a profile rather than to test hypotheses (Collins, 1999). Rather than systematically varying the conditions of learning a single variable at a time in the laboratory, a design experimenter examines multiple dependent variables in order to develop a qualitative profile linking different instructional conditions with corresponding effects on learning within a complex social milieu. Developing profiles is particularly useful for an investigation of actor-oriented transfer. By altering the conditions of learning across design cycle iterations and then seeing how the nature of students' actor-oriented transfer changes, researchers can develop a useful profile of the types of relations of similarity that students create given different types of instructional experiences. This may pave the way for predictive models of the types of connections students make in specific conceptual domains, as well as elaborate how those connections depend upon students' initial instruction within the classroom.

Finally, design experiments are often framed by an intent to theorize about particular learning processes for which the design experiment is seen as a paradigm case (Cobb, Confrey, diSessa, Lehrer, & Schauble, this issue). This theorizing activity can involve issues of transfer on at least two different levels. On the first level, shifting from a traditional to an actor-oriented view of transfer opens up a different set of research questions to explore, and consequently a different arena for theorizing. For example, in the GenScope project, the research question with respect to transfer was "Did transfer occur?" In contrast, within an actor-oriented transfer framework, one assumes that learners are making connections between situations nearly all the time, guided by aspects of the situation that they find personally salient. Consequently, the critical issue is to figure out which connections they make, on what basis, and how and why those connections are sometimes productive. Thus, design experiments can serve as sites for theorizing about connections between the nature of generalizing and features of classroom environments that support generalizing. On a second level, the actor-oriented transfer model presented more formally in the next section of this article is one example of how a larger epistemological theory can evolve from several years of design experimentation.

The Actor-Oriented Transfer Model Compared to Other Models of Transfer

The theoretical assumptions of the actor-oriented approach are summarized in Table 1 and are compared with the assumptions of the traditional transfer paradigm. The first five dimensions address the conception and measurement of transfer and have been illustrated in this article. Three additional dimensions highlight the active and situated nature of transfer in the actor-oriented perspective. These three dimensions have also recently been addressed by other researchers working to expand or reconceive the transfer construct. For example, Greeno, Smith, and Moore (1993) redefined transfer to be consistent with a situated cognition perspective, focusing on issues of invariance and alternative transfer processes (Dimensions 6 and 7). Under this redefined view, transfer involves an attunement to the affordances and constraints of the material artifacts and social environments that are invariant between learning and transfer situations. The actor-oriented transfer approach evolved through my efforts to extend these theoretical ideas to empirical studies. Along the way, my approach came to emphasize learners' personal perceptions of affordances in a way that is both akin to Piaget's (1977) notion of generalizing assimilation, yet also accounts for the structuring roles of artifacts (e.g., the particular affordances of slides in the slope example) and the social structuring of language and actions by more knowledgeable others (Lobato, 1996). Additional aspects of social structuring (Dimension 7) can involve changing forms of social organization such as leading activities, power structure, and social status (Beach, 1999).

Table 1
Theoretical Assumptions of Actor-Oriented Transfer Compared to Traditional Transfer

Dimension	Traditional transfer	Actor-oriented transfer
1. Definition	The application of knowledge learned in one situation to a new situation.	The personal construction of relations of similarity across activities, (i.e., seeing situations as the same).
2. Perspective	Observer's (expert's) perspective.	Actor's (learner's) perspective.
3. Research method	Researchers look for improved performance between learning and transfer tasks.	Researchers look for the influence of prior activity on current activity and how actors construe situations as similar.
4. Research questions	Was transfer obtained? What conditions facilitate transfer?	What relations of similarity are created? How are they supported by the environment?
5. Transfer tasks	Paired learning and transfer tasks share structural features but differ by surface features.	Researchers acknowledge that what experts consider a surface feature may be structurally substantive for a learner.
6. Location of invariance	Transfer measures a psychological phenomenon.	Transfer is distributed across mental, material, social, and cultural planes.
7. Transfer processes	Transfer occurs if two symbolic mental representations are identical or overlap, or if a mapping between them can be constructed.	Multiple processes, such as an attunement to affordances and constraints, assimilation, language use, and "focusing phenomena," influence transfer.
8. Metaphor	Static application of knowledge.	Dynamic production of "sameness."

Finally, rethinking the metaphor for transfer (Dimension 8) is informed by Bransford and Schwartz's (1999) "preparation for future learning" approach. They view transfer as an active process rather than a passive end product of a particular set of learning experiences. The actor-oriented perspective incorporates this insight by replacing the static metaphor of transfer as application with the dynamic metaphor of transfer as the production of sameness. Relations of similarity are produced or constructed, not simply perceived or encoded (Lobato & Siebert, 2002). In sum, the actor-oriented transfer approach capitalizes on the insights from these other research efforts, while developing more fully the important perspective of identifying the particular conceptions that link two situations from the world view of the learner.

Conclusion

Issues of transfer should contribute to design decisions in the iterative cycles of design experiments. However, the assumptions underlying one's model of transfer will affect how the design experiment evolves. Traditional models rely too heavily on the determination of transfer from an expert's point of view and, as a result, can lead to design decisions that are not informed by the specific generalizations that students have formed. In contrast, the actor-oriented transfer approach focuses on the processes by which learners form personal relations of similarities across situations, whether or not those connections are correct or normative, and on the specific ways in which the instructional environment affords and constrains learners' generalizations. This information can, in turn, inform design decisions. Thus, even when things go wrong, as they often do in the initial stages of design experiments, the actor-oriented approach provides a principled method for profiting from an investigation of students' "incorrect" generalizations.

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